Faculty of Engineering and Information Technology

Computer Engineering Department

Graduation Project II

Smart Merchandise Storage

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Presented in partial fulfillment of the requirements for Bachelor's degree in Computer Engineering.

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Acknowledgment

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Disclaimer Statement

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Abstract:

The wholesale industry faces a plethora of challenges including security, effective distribution, and safe handling of goods. In this project, a Smart Merchandise Storage system for wholesalers is demonstrated. It is intended to improve security, operational effectiveness, and safety. The system combines an XYZ arm mechanism with RFID technology, Google Assistant speech recognition, and a mobile application created with Blynk. The solution efficiently optimized ordering and retrieval, restricted access to storage, and delivered real-time emergency and out-of-stock messages, despite restrictions like the cap on voice commands at two and the use of demo versions of the application.

This project serves as a useful learning opportunity in the integration of hardware and software, problem-solving, and the practical application of theoretical knowledge. It also shows the possibilities of combining several technologies for an all-encompassing solution. Future development will involve enlarging storage spaces, putting AI recommendations into practice, creating an RFID or barcode-based refilling technique, establishing a conveyor belt system, and using infrared sensors for real-time inventory updates, among other things.

Chapter 1: Introduction

There is a rising need to offer solutions that are effective, safe, and innovative given the constantly shifting environment of the wholesale industry. The issues of security, effective distribution, and safe handling take on greater importance when major wholesalers deliver goods to retailers. With the use of cutting-edge technology, the Smart Merchandise Storage project offers a comprehensive answer designed specifically for wholesalers.

1.1 Problem Statement:

Wholesalers face a variety of unique obstacles:

- When retailers utilize storage locations for their inventory, maintaining security becomes challenging.
- Bulky objects and big boxes should never be handled and distributed since it might be risky.
- Manual inventory management might result in improper stock management, which can impair the regular supply to merchants.
- Large storage rooms may conceal safety risks, putting people and inventory in danger.

1.2 Objectives:

Our project pursues several goals and is specifically targeted at the wholesale industry. We seek to strengthen security measures so that only authorized retailers can easily use the system to make purchases, protecting the goods. In terms of operation, we want to effectively handle big and heavy merchandise boxes using the XYZ arm mechanism to drastically eliminate manual handling. Additionally, the development of voice recognition and keypad technologies is expected to transform the way that orders are placed, giving businesses an unmatched level of convenience when placing big orders. Additionally, safety is improved because our technology is built to detect dangers like fires and send timely alerts. Last but not least, it is impossible to emphasize the significance of inventory management. Our system guarantees to keep wholesalers informed about stock levels via automatic alerts, ensuring a continuous and efficient supply chain for retailers.

1.3 Significance of the work:

The Smart Merchandise Storage project is not just another technological endeavor—it's a transformative venture for the world of wholesalers. y facilitating order placements without necessitating direct access to the storage, we mitigate risks stemming from mishandling or unauthorized intrusions. Coupled with this enhanced security is an operational efficiency that translates to faster services for retailers. This expedited service not only improves the retailer experience but also significantly increases the number of customers a wholesaler can serve in a day. Such operational enhancements naturally pave the way for increased economic gains, allowing wholesalers to reap improved profit margins. This project, therefore, stands as a testament to how technology can recalibrate the dynamics between wholesalers and retailers.

1.4 Organization of the report:

In this report, we illustrate the idea in its full detail. Going through the report, you can first see the constraints we faced during our work, the standards and used technologies, and earlier coursework. Then, a background about the topic has been discussed, and what special features we have added to our project. After that, the methodology of our work is extensively explained. The next chapter discusses the results. Ending it up with the conclusion of the whole work and what is our vision for the future to improve our work.

Chapter 2: Constraints, Standards/ Codes, and Earlier Coursework

2.1 Constraints:

The mechanical component of the project presented the greatest challenge because, as computer students, we had never installed mechanical parts of this complexity, For example calibrating the belt tension level was challenging cause it vibrates when it's tightened.
In addition to being unavailable in the shops, we needed a design that could support the weight while also allowing it to move freely on its rails.
In addition, it was difficult to work with little electrical parts like drivers and small chips since they are sensitive to variations in voltage, current, and even the weather.
For example, we face a problem with the ESP8266 to get the database due to internet interruption.

2.2 Standards and codes:

We need external libraries to implement our project, the **Keypad** library for using matrix style keypads with the Arduino, **LiquidCrystal_I2C** library for the reimplementation of the standard Arduino LCD library which allows to control of I2C displays with functions extremely similar to LiquidCrystal library, and the **RFID** library to read and write different types of Radio-Frequency IDentification (RFID) cards on your Arduino using a RC522 based reader connected via the Serial Peripheral Interface (SPI) interface.

2.3 Earlier coursework

Working on our project depends on some courses we learned either within the Computer Engineering program or self-learning sources such as:

- Microcontrollers Course:
  Basic knowledge about the PIC Microcontroller and how to program hardware components is provided by the microcontroller. Additionally, the lab for this course explains how to download code onto the PIC Microcontroller equipment and how to comprehend each pin and feature there. Because the laboratory for this material played a major role in assisting us in initiating work on the project, it is one of the most crucial materials that helped us comprehend how to deal with the Arduino Mega components of the project.

- Electronic circuits Course:
  Because it teaches us the fundamentals of dealing with a variety of circuits and how to wire them, this course has primarily helped us with dealing with electrical circuits and related connections.

- CPU lab:
  This course gives us the required skills to design a complete project, dealing with real hardware components such as connecting and welding wires.

- Databases Course:
  Database course was like a gateway for us in learning front-end and back-end and dealing with real databases.

- Web Programming Course:
  This course helped us to design a web page using PHP, HTML, and CSS which we used to build our website portal interface with.

- Critical Thinking Skills Course:
  We used critical thinking skills course which helped us write this report.

Chapter 3: Literature Review

According to numerous studies, the development of goods storage systems has notably moved away from crude, manual approaches and toward more sophisticated, technologically advanced solutions. The Internet of Things (IoT) and technological advancements like RFID tags and voice recognition technologies, which have been essential in streamlining inventory management and improving the order processing experience, have had a big impact on this change.

The deployment of robotic XYZ arms has also markedly advanced warehouse management. These mechanisms stand out for their effectiveness in moving objects, providing task precision, and maximizing space usage, while also attending to important safety and security issues.

These technological integrations aim to change the operational environment for retailers and wholesalers. Both sides stand to gain by improving the supply chain and making sure orders are filled quickly and precisely, enabling a more effective and dynamic commerce ecosystem.

Chapter 4: Methodology

In light of what we have discussed above, it is evident that the project has significance and advantages over traditional methods.
In this project, we combined both software and hardware to control the machine. And we will talk about what components we are using in our project.

4.1 Hardware components:

The following list contains the hardware components that we have been used in our project:

- **Arduino Mega 2560:**
  The Arduino Mega 2560 is a microcontroller board based on the ATmega2560 chipset. It is a flexible and strong board that is frequently used in robotics and electronics projects. Due to its wide variety of input and output pins, the Arduino Mega 2560 is appropriate for complicated applications that need numerous connections. The Arduino Mega 2560 has a significant amount of flash memory, 16 analog inputs, and 54 digital input/output pins, which is more than enough to handle many sensors, actuators, and other electronic components. It also has a built-in USB interface for simple computer programming and communication.
  Because the board is compatible with the Arduino programming language, both novice and expert users will find the development process to be much simpler. It supports a wide range of libraries and community-contributed code,
  allowing users to leverage existing resources for their projects.

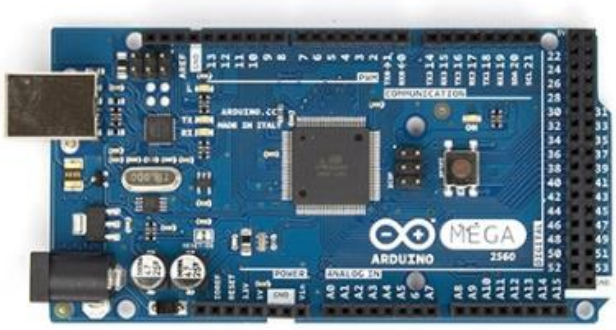

Figure 1: Arduino Mega 2560

- **Stepper Motors:**
  We've included stepper motors because they are crucial to the exact movement capabilities of our XYZ arm system. Contrary to conventional motors, stepper motors move in discrete steps, making precise positioning control possible without the use of a feedback device. Because of this special characteristic, they are the best option for applications that require accuracy, like our system for retrieving products. The XYZ arm can precisely locate and retrieve things from certain locations inside the storage system because each step taken by the motor corresponds to a particular degree of rotation. These motors have been matched with A4988 driver and control algorithms to ensure smooth, precise, and effective movement over the entire operational range of the arm. This integration assures quick and accurate product retrieval while also adding to the system's overall dependability and endurance.

  In the context of our Smart Merchandise Storage project, the XYZ arm mechanism uses stepper motors to enable three-dimensional movement:

  -X-axis control: Enables the arm to traverse left or right.
  -Y-axis control: Enables forward or backward movement.
  -Z-axis control: Enables the arm to move up or down.

  The discrete, regulated movement of stepper motors is important given the size of our storage area and the need for pinpoint accuracy in product retrieval. The technology calculates the precise location of the product when a retailer places an order. The stepper motors of the XYZ arm are then precisely guided by this location through a series of pulses, allowing for the precise retrieval of the merchandise.

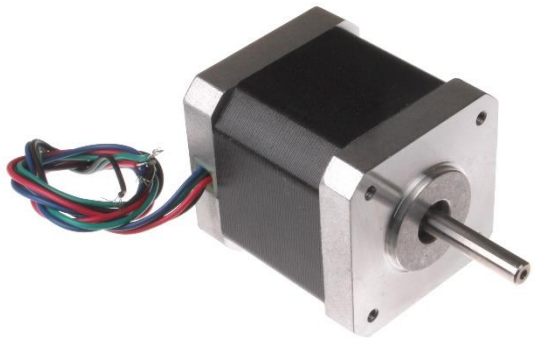

Figure 2: Stepper Motor

- **A4988 driver:**
  While stepper motors are effective at providing accurate positioning control, a customized interface is necessary for the best performance. To ensure controlled and accurate movement of the XYZ arm mechanism in our Smart Merchandise Storage project, we've chosen the A4988 stepper motor drivers to fill the gap between the microcontroller (Arduino Mega) and the stepper motors.

  We may use just two pins and the stepper motor driver to control the speed and direction of bipolar stepper motors.
  The MS1, MS2, and MS3 pins of the driver provide a variety of possibilities for microstepping settings. The Full step mode was determined to be the best option for our project.
  The driver relies heavily on the STEP input to regulate the motor's microsteps. The motor moves a specific number of micro-steps as indicated by the microstrip selection pins with each HIGH pulse provided to this pin. The motor's rotational speed is directly influenced by the pulses' frequency.

  The DIR input in the driver also controls the motor's direction of rotation. The motor rotates clockwise when it is pulled HIGH, and counterclockwise when it is pulled LOW. This gives us the freedom to adjust the motor's movement to suit the needs of our project.

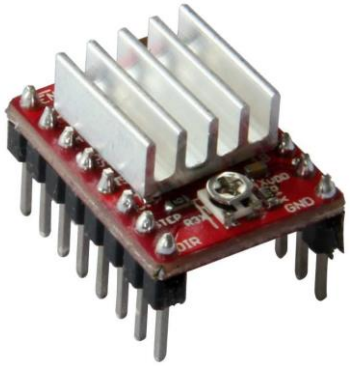

Figure 3: A4988 Driver

We connect the stepper motor with the driver in Figure 4 below.

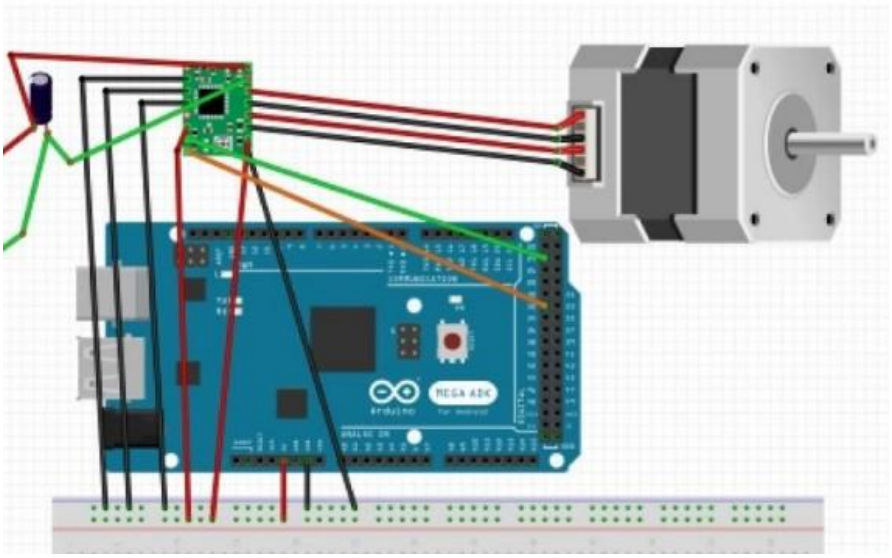

Figure 4: Stepper Motor and Driver connection

- **LCD:**
  We've included an LCD with an I2C interface in our Smart Merchandise Storage system, to show system feedback and status to the retailer, greatly simplifying the connection process. The VCC, GND, SDA, and SCL cables are the only ones that are necessary to connect the LCD to the Arduino Mega. This design decision not only simplifies the setup but also highlights the LCD's popularity in Arduino projects due to its simplicity of integration and less complicated cabling.

Figure 5: LCD

- **Keypad:**
  Our Smart Merchandise Storage system has a 4x4 keypad for a more enhanced and haptic user experience. With 16 buttons, this matrix-style keypad is a great solution for merchants to enter product codes, and quantities, or to browse through other system features. The keypad gives retailers a direct and easy way to place their specific amount of products, rather than only relying on voice instructions or automated procedures. Its integration offers a fail-safe ordering process, which is advantageous in settings where background noise could interfere with voice recognition or when the store prefers a manual input method for accuracy. The 4x4 keypad reinforces the project's dedication to user-friendliness and operational versatility when combined with the system's other interfaces.

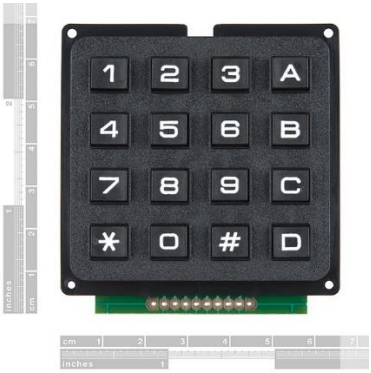

Figure 6: Keypad

- **RFID:**
  RFID technology has been effectively integrated into the Smart Merchandise Storage system to improve and speed the payment process. Radio-frequency identification, or RFID, makes use of electromagnetic fields to automatically recognize and track tags affixed to things. These tags are included in the cards that are given to each store in our system. Each card is uniquely identified and connected to the retailer's account. Retailers only need to submit their RFID cards to the system's scanner to complete a transaction. The system then reads and scans the card, locates the corresponding account, and quickly and securely completes the payment. This strategy ensures correct and timely transactions by speeding up the payment process and reducing manual input errors.


Figure 7: RFID

- **Limit Switches:**
  Limit switches serve as the mechanism that tells the computer the limits of the machine. These switches serve as sensors, identifying and relaying to the controlling computer the physical limits of the arm's movement. Once the arm has reached its maximum or minimum extent along its X, Y, or Z axis, it may make contact with a limit switch. The switch is actuated upon touch, alerting the computer that the arm has arrived at its limit.

Figure 8: Limit Switch

- **ESP8266:**
  The ESP8266 Wi-Fi module is used by the Smart Merchandise Storage system to connect the Arduino to a central database and numerous user platforms. This module allows the Arduino to retrieve real-time information about retailer accounts and product statuses. The technology also integrates with the Blynk app, which serves two purposes: it makes it easier for businesses to accept mobile orders and it sends out notifications like fire alerts and out-of-stock notices. Additionally, Google Assistant integration allows for simple voice-commanded interactions, increasing user convenience. The ESP8266 functions as the system's communications backbone as a whole, providing smooth, knowledgeable, and effective operations.

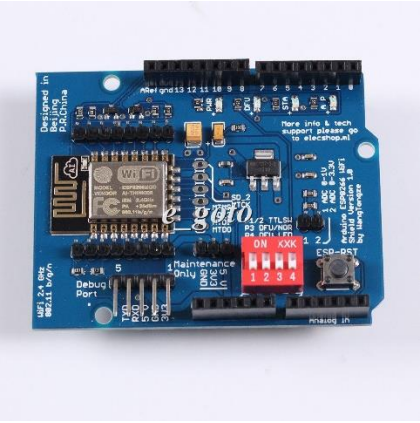

Figure 9:ESP8266

- **Flame Sensors:**
  Flame sensors are included in storage rooms as part of the Smart Merchandise Storage system for maximum safety. Upon spotting possible fires, these sensors instantly relay signals by detecting infrared wavelengths from flames. Real-time notifications are sent to the storage owner via the Blynk app via the Arduino and ESP8266 module, ensuring quick response to any fire hazards and highlighting the system's commitment to safety.

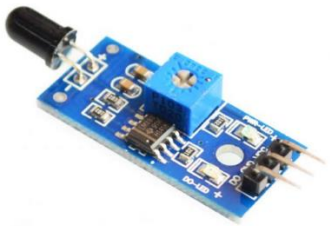

Figure 10: Flame Sensor

- **Servo Motor:**
  Our system uses an XYZ arm equipped with a claw, controlled by a servo motor, to handle merchandise. The arm moves to the designated box after receiving the order. The servo motor guarantees accurate grip adjustments, enabling the claw to safely and securely grab the box. It then sends the package to a preset location for retailer pickup, providing effective and cautious handling throughout the wholesaler to retailer distribution process.

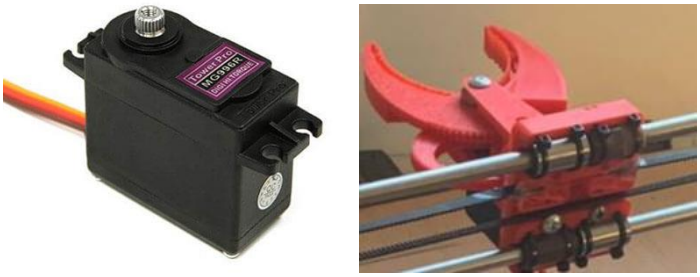

Figure 11: Servo Motor and Claw

- **Buck-Boost Converter:**
  As we face noise and vibration in the servo motor we need to connect the buck-boost converter. It is an essential part of our project because it ensures the servo motor powering the claw mechanism operates smoothly, safely, and effectively in grabbing items. Despite variations in the input voltage, it provides a consistent, controlled voltage that reduces noise, vibrations, and hesitations in the servo motor, resulting in accurate control, optimal performance, and a decreased risk of product damage.

  A buck-boost converter regulates voltage levels by either boosting or bucking them to produce a constant output voltage regardless of changes in the input voltage. To maintain a consistent output, which is essential for delicate electronics like servo motors that need a stable power supply for maximum operation, it cycles between two modes, buck and boost.

Figure 12: Buck-Boost Converter Module

- **Cooling Fan:**
  To avoid overheating and thermal damage to the stepper motor drivers, we connect a cooling fan. The fan's active cooling mechanism absorbs heat, keeps driver temperatures within the desired range, prevents thermal shutdown, increases component longevity, and ultimately improves the system's overall dependability and efficiency.

Figure 13: Cooling Fan

- **Power Supply and Regulator:**
  We used a 12-volt power supply and linked L7805 regulator in our system to provide steady and dependable power for all components. The regulator makes sure the voltage and current stay within predetermined limits, regardless of input fluctuations or load variations, while the power supply transforms AC from the mains to the necessary DC voltage. In addition to preventing damage from overvoltage, overcurrent, or short circuits, this improves the system's general functionality, safety, and dependability.

Figure 14: Power Supply and Regulator

4.2 Mechanical Parts:

- **Axes Mechanism:**
  To ensure the exact location and movement of the arm and claw, the mechanical framework of the project has been precisely built. The squared black aluminum tube that serves as the structure's y-axis is an important part of it. This tube comprises a spur gear, pulleys, and a GT2 belt that enable the arm to be moved along the y-axis while also acting as a rigid basis for attaching the arm to the wooden base.

  -Y-Axis: Made of a squared aluminum tube, the y-axis serves as the foundation of the movement mechanism. The arm is firmly fastened to the hardwood base thanks to this robust structure. A GT2 belt that is attached to a stepper motor and pulleys, which are utilized to move the arm forward and backward on the aluminum tube, makes it possible to move the arm along the y-axis.

Figure 15: Aluminum Tube

-Z and X Axes: Located on the y-axis, the Z and X axes are made up of smooth rods, spur gears, and edges made of 3D-printed plastic. For the arm's movement along the z (up and down) and x (left and right) axes, the smooth rods and plastic edges act as smooth and steady guides. The motors' rotational motion is changed into linear motion along the rods via the GT2 belts and spur gears.

Linear rails were initially thought of for the project due to their easy attachment to the frame, smooth motion, and lack of bends. They were, however, disregarded because of their costly price (400 Nis per meter) and the extra weight they would contribute to the building. Smooth rods were chosen instead since they are more affordable and offer smooth movement. Given the project's budget and weight restrictions, they were thought to be the best alternative despite certain drawbacks including their imperfect straightness (some bends may be present) and difficulty attaching to the frame.

Figure 16: Smooth Rod

Figure 17: GT2 Belt and Pulleys

-Claw: The x-axis contains a 3D-printed claw, which is used to grip the items from the storage. The claw is fixed onto the rods and belt of the x-axis and contains spur gears controlled by a servo motor. The servo motor opens and closes the claw by rotating the spur gears, enabling it to grip and release items.

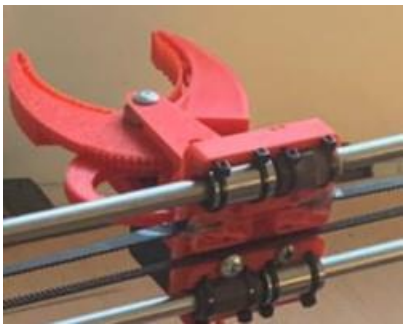

Figure 18: Claw

4.3 Programs:

- We used **Arduino IDEs** for programming the microcontrollers and all used hardware.
- **VS code** to build the website.
- **Xampp**, **PhpMyAdmin** for database control.
- **Fritzing** to design the circuits.
- **Blynk** for mobile application.
- **Google Assistant** to enable voice commands.

4.4 Circuit Connection:

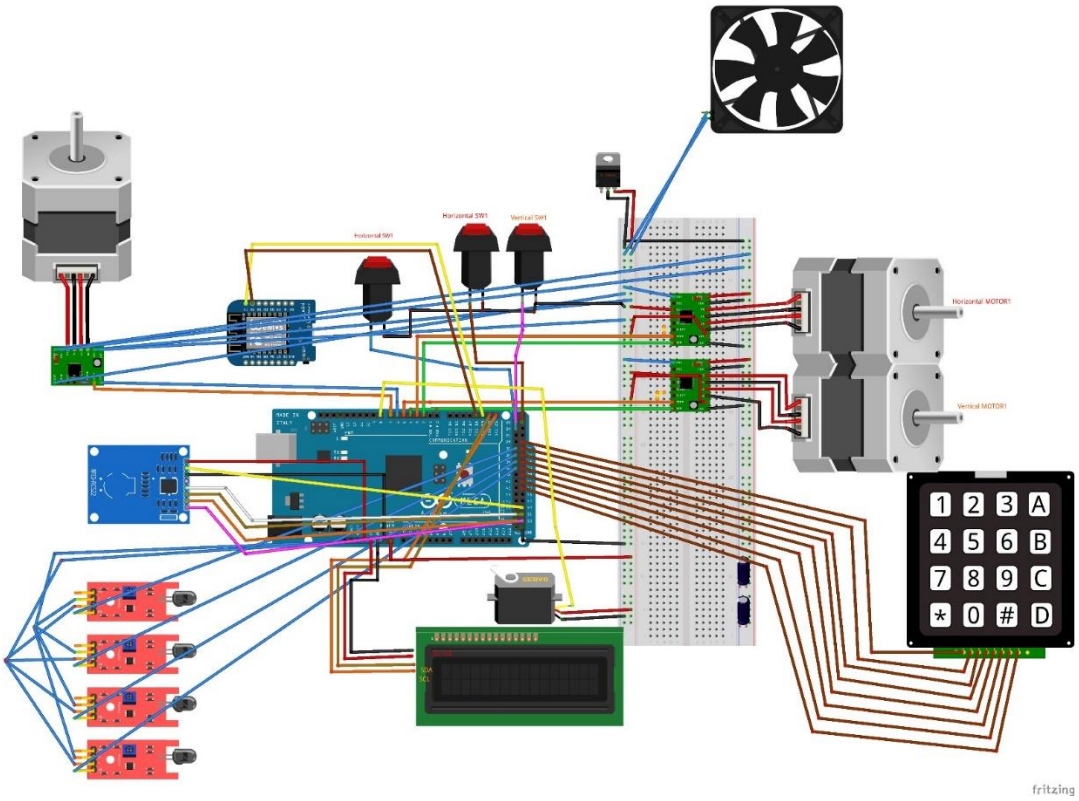

Figure 19: Circuit Connection

4.5 Software:

- **Website:**

The website built for our system acts as the admin page for the storage owner, giving them access to tools for managing store accounts and product inventory. The owner of the storage facility can add more RFID cards for additional retailers and link them to a certain dollar amount. The system updates the money amount if the card ID is already present; if not, a new user account with the requested money amount is created. In addition, the owner can alter the prices of current products or add new quantities of existing products to the inventory. As a demo version, the current version of the website is intended exclusively for currently available products because of hardware restrictions, which should be noted. However, technology that enables the addition of new items to the website could be introduced in the future, expanding its performance and making it a more complete tool for storage owners.

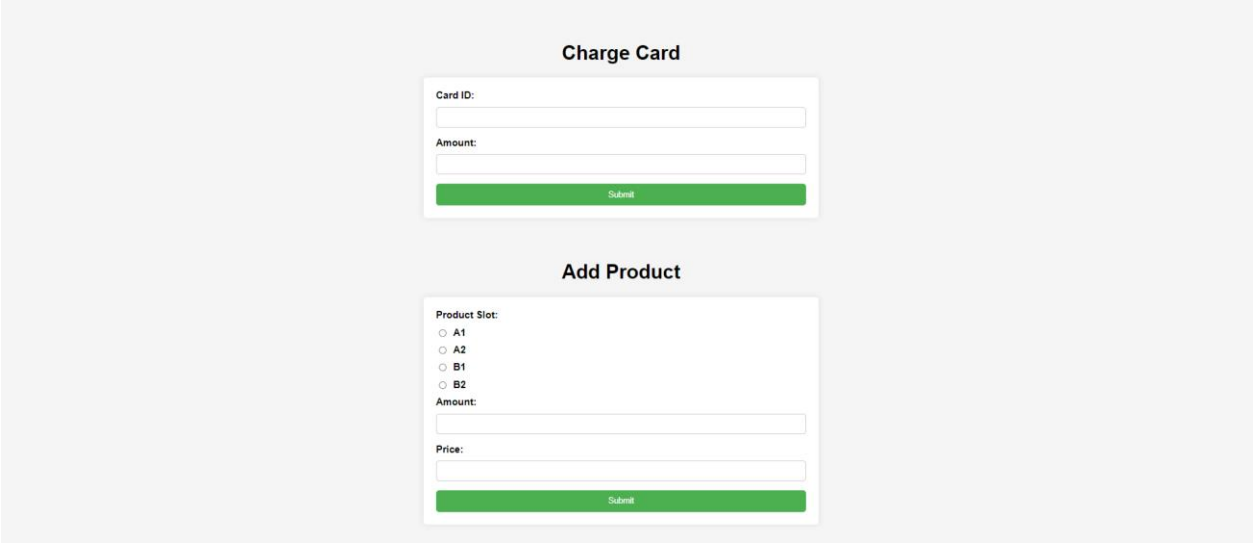

Figure 20:Admin Website

- **Mobile Application:**
  We design mobile application for our system using Blynk, which is a platform that enables quick and simple creation of mobile applications for IoT projects. The application replaces the keypad for placing orders and offers a user-friendly interface for doing so. The application is also used to notify the storage owner of alerts that have been sent. These alerts contain crucial information like out-of-stock and fire alerts, ensuring that the storage owner is made aware of any urgent situations or inventory problems right away. Because it allows for both order placing and alarm alerts.

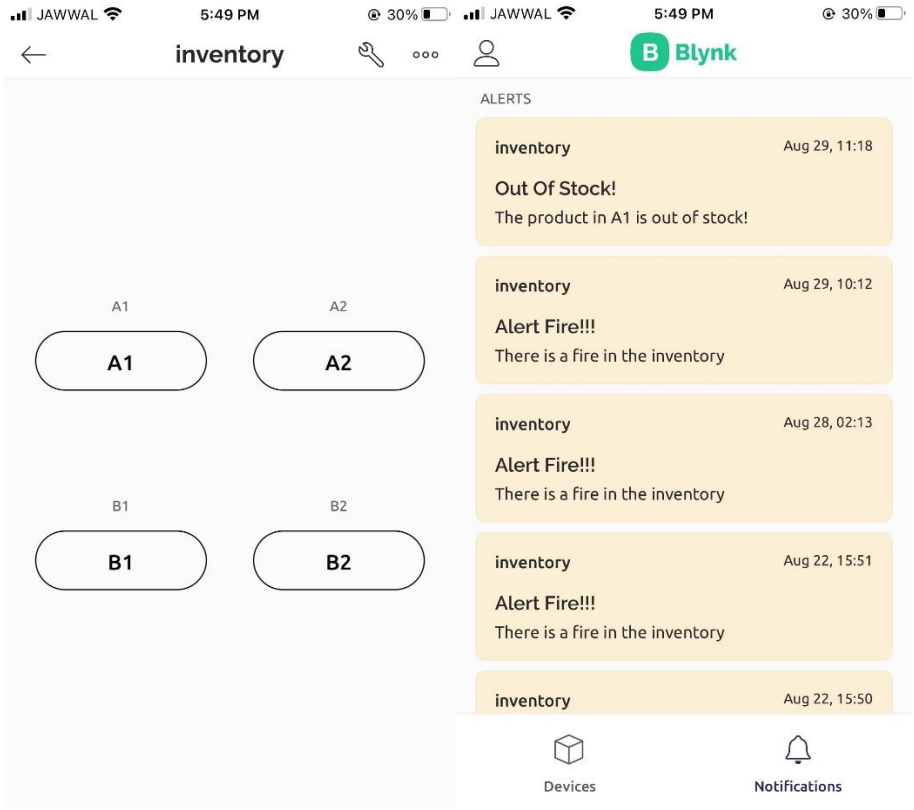

Figure 21: Mobile Application

- **Google Assistant:**
  Our system also has voice recognition capabilities thanks to Google Assistant integration. It is connected directly to the Blynk application via APIs, which translates the voice commands into orders and then sends them to the machine. Only two voice commands were activated for the demo version of the system due to the restrictions of the service's free tier. Despite this restriction, the Google Assistant integration shows the system's potential to include innovative features like voice recognition, making the process of placing and retrieving orders even more effective and practical for the retailer.

  We used IFTTT (If This Then That) and webhooks to effortlessly link Google Assistant with the Blynk mobile app in our project for smart merchandise storage, allowing voice commands to operate the system. We identified several speech triggers that, when spoken to Google Assistant, started actions using custom IFTTT applets. These triggers were set up to make HTTP POST requests to a URL for a webhook. These requests were received by a webhook listener on the Blynk side, which translated them into instructions for the Blynk app to carry out the appropriate activities.

Chapter 5: Results and Discussion

The Smart Merchandise Storage system was successfully designed, incorporating speech recognition with Google Assistant, RFID technology, and a mobile application created with Blynk. For wholesalers and retailers, this led to the creation of a safe and effective system that streamlined the ordering and retrieval process, improved security by restricting access to storage, and offered real-time notifications for fire emergencies and out-of-stock scenarios.

Due to Google Assistant's free version, the voice recognition feature was restricted to only two commands, and the project's website and mobile application were created solely for existing items since it was a demo version.

This project provided a priceless opportunity to gain skills using hardware components and Arduino programming. The integration of numerous parts, including RFID technology and the XYZ arm mechanism, necessitated a thorough knowledge of hardware and software development. In addition to improving technical skills, this procedure also strengthened problem-solving capabilities as numerous difficulties developed throughout the integration of various components. The project also demonstrated how theoretical knowledge can be applied practically and emphasized the value of ongoing testing and problem-solving throughout the development process.

Chapter 6: Conclusion

In conclusion, the Smart Merchandise Storage system successfully addressed several issues that retailers and wholesalers encountered, offering a reliable and effective solution for product ordering and retrieval. The XYZ arm mechanism and safety features, together with the integration of RFID technology, speech recognition with Google Assistant, and a mobile application created using Blynk, demonstrated the potential of merging several technologies to create an all-encompassing solution.

The project was a great learning opportunity despite its drawbacks, which included the restricted voice recognition capability and the sample versions of the website and mobile application. It improved technical ability for integrating hardware and software, and problem-solving skills, and gave real-world examples of how to put theory into practice.

As technology develops further, there is an increasing need for creative solutions that improve security, expedite operations, and send out emergency notifications in real-time. To suit the changing needs of the wholesale and retail industries, the Smart Merchandise Storage system can be improved upon and modified.

Chapter 7: Future Work

The Smart Merchandise Storage system has shown positive results in its present configuration, but there are still several ways it can be developed and enhanced:

- **Expand storage capacity:** Add extra storage rooms to hold more goods, enabling the system to manage a greater inventory and serve a wider range of businesses.

- **Artificial Intelligence Recommendations:** Put in place an AI program that examines previous orders and makes suggestions to retailers, supporting them in making better choices when placing orders.

- **Restocking Method:** Create a technique for replacing stock that relies on RFID tags or barcodes to streamline the process of restocking inventory and make sure that the storage is always fully stocked.

- **Conveyor Belt System:** Install a conveyor belt system at the receiving window to make transporting boxes to the truck easier, which will cut down on manual labor and speed up delivery.

- **Infrared Sensors for Product Confirmation:** Use infrared sensors to detect the presence of products in the storage areas, delivering real-time inventory updates and aiding in the avoidance of stockouts.

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